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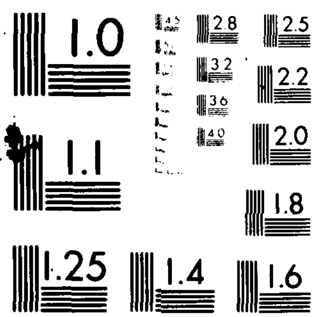

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A new concept of a buoy design which offers promise of a small lightweight buoy, which is easily deployed from a small craft and which reduces the roll of the mast induced by wave action.

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STABILIZED PLATFORM BUOY

I. INTRODUCTION

In at-sea experiments a requirement frequently exists for mooring a vertical mast which floats on the sea surface. In many applications an advantage is gained by preventing the ocean wave motion from inducing out-of-vertical motions of the mast. For example, if the mast supports an RF telemetry antenna, stabilizing the orientation of the mast permits the use of highly directional antennas to increase the telemetry range.

In the past vertical stability has been achieved by using very large buoys, which are difficult or impossible to deploy from a small craft or in rough seas. This report documents a buoy design which offers promise of a small lightweight buoy, which may be easily deployed from a small craft and which reduces the roll of the mast induced by wave action. Results of a sea trial of a prototype buoy are also presented.

II. STABILIZED PLATFORM BUOY

A. Design Requirements

A constraint on the design was that the buoy was be deployed from a small craft. Thus the buoy had to be small and light enough to be deployed in a moderate sea by very few deck hands, and without the aid of heavy hoisting equipment which is found on larger vessels.

Since the buoy was to be anchored for a period of time it had to be rugged enough to survive storms and heavy seas. Material selection, durability, and strength of components were important considerations.

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There was a need for the buoy to be very simple to avoid the complicated buoyancy trimming procedures that some systems required before deployment. To facilitate deployment the buoy was made so it could be completely assembled before the launch procedures began.

Another requirement was that the buoy be quiet. Since the buoy was to be used in an experiment which measured acoustic ambient noise in the ocean, it was essential that it did not introduce noise from the system into the water.

In spite of these constraints if was necessary that the main objective be met; that is that the mast be held vertical and follow the sea surface under moderate sea and current conditions.

B. Design Details

The basic design of the buoy is shown in Fig. 1. The mast rides the ocean surface due to the vertical support provided by a large displacement float. The mast is held vertical by mounting it on a long rigid counterweighted rod. To prevent torque on the float induced through wave action and from force from the mooring line from being transmitted to the mast, the mechanical connection between the float and the mast is gimballed. A torus shape was chosen for the float, so it could rotate freely in a vertical plane through a large (58°) angle without touching the mast.

The section of mooring line attached to the float was held near horizontal by means of an auxiliary float attached to the mooring line. By attaching to the outside wall of the floatation collar the mooring line was prevented from putting torque on the mast. The second float was used to prevent set of angle of the float by mooring stress (see Fig. 8). Details of the construction of the float, mast, and gimballed joint of a prototype buoy are given below.

A large displacement cylindrical torus float was designed (Fig. 1) to permit the buoy to follow sea surface vertically. The shell of the float was constructed from 1/16" 6061 thin wall aluminum. This shell was filled with the buoyant material isofoam P.E. 2 to exclude water. This is a two-component polyether-based system which produces a low density .03g/cm^3 (2 lbs/cu ft) rigid urethane foam. A hard-based epoxy resin was used to coat the urethane foam to prevent the absorption of water.

An aluminum ring, which served as a strength member for the attachment of the mast, was incorporated into the floatation collar. This ring was constructed from a flat aluminum stock 5 cm × 1.2 cm (2" × 1/2") (Fig. 2). On the inside of the ring 6 padeyes were welded at 60° intervals. Two gussets, one on the top and one on the bottom of each of the 5 cm × 1.2 cm × 15 cm (2" × 1/2" × 6" padeyes, were welded to give the padeyes added reinforcement. Each of the eyes became a suspension point of the gimballed joint.

Six aluminum padeyes were welded around the mast 91 cm (3 ft) from the top as shown in Fig. 3. These eyes were attached to the eyes along the interior circumference of the float, thereby providing support for the mast. At the top of the mast, an aluminum plate was welded as shown in Fig. 1, for use in securing instrumentation. In the at-sea test a light was mounted on this platform (see Fig. 4).

To provide the gimballing elastic exerciser cord was used to connect the eyes welded to the mast to the suspension points of the float (Fig. 1). This coupling not only provided a low friction torque relief but also reduced the stress of the structure accompanying the vertical motion of the buoy. The stiffness of the mount was chosen to provide a natural frequency of oscillation of about one (1) Hertz. This frequency was chosen to be higher than the wave periods (~0.1 Hz) to prevent wave-induced resonances which would fatigue the mount. The required stiffness, K, is given by[1]:

$$K = 4\pi^2 f^2 m \quad (1)$$

where f is the resonant frequency desired and m is the mass of the mast. The needed stiffness was determined from Eq. (1) using the mass of the mast as determined below. The value obtained for the stiffness 1300 NT/M (89 lb/ft) was verified by measuring the suspension's extension by a known force.

A rigid counterweight mast was used to provide the righting moment. This mast was made slender to reduce drag due to ocean currents. Two-inch aluminum pipe was chosen for the mast tubing because it is more rigid than solid rod of the same weight. The mast was made in four sections. The three underwater sections were each 5 feet long, and the top section, which supported the instrumentation, was thirty-eight inches in length.

The choice of the mast length will depend upon the ocean current conditions expected. In the discussion below wind drag is ignored. The drag force per unit length (F) due to the water flow is given by[2]:

$$F = 1/2 \rho u^2 d\, C_D$$

where ρ is the fluid density, d is the diameter of the mast, u is the flow speed and C_D is the drag coefficient. We obtain C_D from graphs and the Reynolds number, R where:

$$R = \frac{ud}{\gamma}$$

and $\gamma = 10^{-2}$ cm/sec is the kinematic viscosity of water. A typical Reynolds number in this application is 2×10^4 so the coefficient C_D is about 1.5. The torque, L_D on the mast due to drag, if the flow speed is assumed to be of uniform value u over the length l of the mast, is then:

$$L_D = 1/2\, l^2 F = 1/4 \rho\, l^2 u^2 d C_D.$$

The restoring torque obtained from a weight, W, at the bottom of the mast is $L_R = Wl \sin\theta$ where θ is the tilt angle measured from the vertical. By equating L_R and L_D we have the equilibrium tilt angle due to current drag:

$$\sin\theta = \frac{\rho\, l u^2 d C_D}{4W}. \tag{2}$$

We see that although increasing the length of the mast increases the restoring moment due to the counterweight in proportion to the length, the moment due to drag increases with the square of the length. Thus the tilt angle in Eq. (2) increases with the mast length. The approach taken in making the prototype was to select the minimum mast length necessary to place the bottom of the mast well below the wave action and then to determine the counterweight from Eq. (2) using the maximum acceptable tilt angle and the expected current speed.

The length was chosen to be 4.5 meters. Then the requirement that the mast not tilt more then four degrees in a one knot current and the use of Eq. (2) gives the weight in water needed to provide the necessary restoring torque; the weight thus determined was 312 NT (70 lbs). Lead ingots were inserted into the bottom of the mast to provide the counter weight.

An articulated joint was built into the mast in order to assist deployment and to help prevent damage to the long lever arm during deployment. This was designed as an aluminum insert between the bottom of the instrumentation mast and the top of the subsurface lever arm see Fig. 5.

In launching, the assembled buoy float was lifted by a pendant high enough to clear the deck railing (see Fig. 6). The lever arm was then lifted over the deck rail and lowered into the water by the aid of ropes, which were then slipped off. At this point the buoy and the subsurface lever arm were suspended in a vertical position. Two remaining bolts were inserted into the articulated joint and tightened making the mast rigid.

Flat aluminum stock two inches wide and one half inch thick was set in the center around the outside of the buoy and then welded in place. Four aluminum padeyes were welded on the aluminum flat stock 90° apart. Eyebolts were fastened to the padeyes to provide points of attachment. Two points 180° apart were used for the bridle to raise the buoy for launching and later could be used for retrieval (see Figs. 6 and 7).

A second bridle was made and attached to the second pair of eyebolts. To this bridle was fastened a fifty foot length of half-inch polypropylene line which was secured to a second surface buoy (Fig. 8). Polypropylene line was used because it has a positive buoyancy and its tensile strength (4200 lbs for the piece used).

III. RESULTS OF TANK AND FIELD TESTS OF PROTOTYPE

A. Tank Test

Prior to the fabrication of the prototype which would go to sea a small model was constructed. The floatation collar was fashioned from styrofoam, rubber bands were used in place of exerciser cord, and the mast was one continuous length of thin wall aluminum tubing with a lead weight strapped to the bottom.

The model was placed into a large test tank at NRL. The floatation collar was manually submersed and released, the frequency of oscillation appeared to be (~0.1 Hz). Wave or currents could not be generated in the tank, so motion was induced at the collar. The gimballing between the mast and the collar was excellent: no horizontal component of torque was introduced into the mast by the movement of the collar. To verify if the mast would tilt in an ocean current a string was attached to the outside center of the floatation collar and the model was pulled through the water. This created a slight angle of the mast.

The concept of vertical stability for a mast seemed to be feasible thus the prototype was built.

B. Sea Test of the Prototype

On November 1980 an acoustics experiment was conducted by NRL and the SACLANT ASW Research Center off the northwestern coast of Italy southeast of Elba. A test of the prototype buoy was incorporated into the experiment.

To conduct the experiment the vessel R.V. Manning, a tug boat operated by SACLANT ASW RESEARCH CENTER, was used. The craft was less than one hundred feet in length with one small winch and an electric hoist for handling the equipment.

The buoy was assembled and made ready dockside before the transit to the area. Launching was facilitated due to preassembly and design as previously discussed in Section II.

The retrieval was also simple, the buoy was lifted out of the water where the bolts could be loosened and the articulated joint could be taken apart. The bottom part of the mast was tied and held with ropes while the buoy was taken onboard. Then with very little effort the bottom mast was retrieved.

Photographs were taken of the stabilized buoy platform from the R.V. Manning. Fig. 8 shows the gimballing or decoupling of the mast from the motion of surface float. Measurements made from the photographs indicate a ~3° mast tilt measured using the horizon while the surface float tilts 15°.

Ambient noise data was collected with instrumentation monitored on the island. An array of hydrophones was approximately 100 meters from the buoy. No acoustic noise was attributed to the buoy platform.

About three days after the buoy had been launched, a storm system moved into the area. Gale force winds of thirty to forty-five kts lasted over a period of twenty four hours. A few days later the buoy platform was examined and it was found that there was no noticeable damage to the mast or to the surface float; it had survived the storm.

IV. CONCLUSIONS

Based on an at-sea test of a prototype, the concept and design of the stabilized platform seem to be valid. The gimballing was effective in decoupling the surface wave action from the instrument mast. The buoy also shows a great deal of promise in that it is lightweight, can be handled with few deck hands, can be launched from small vessels, and is not easily damaged by a heavy sea.

V. ACKNOWLEDGMENTS

The author would like to express his appreciation to the SACLANT ASW Research Center, LA, Spezia, Italy for providing the opportunity to conduct the field trial using R.V. Manning. The author also acknowledges helpful suggestions made by Stephen N. Wolf of NRL.

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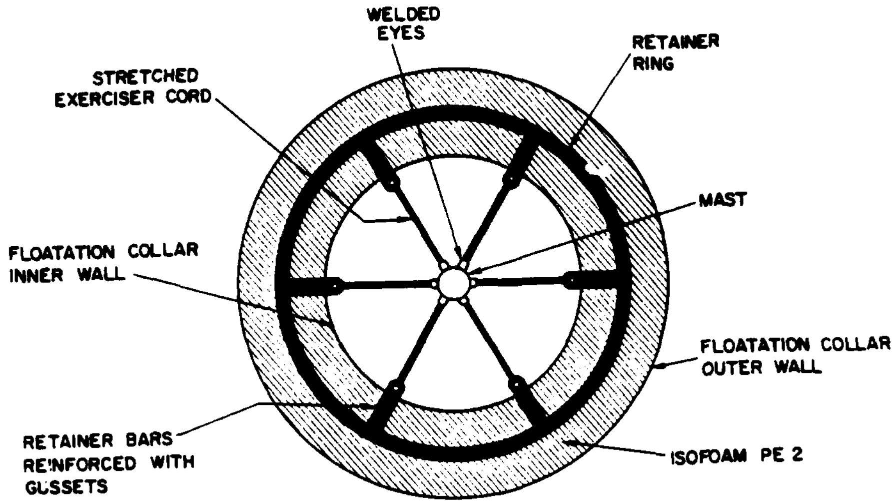
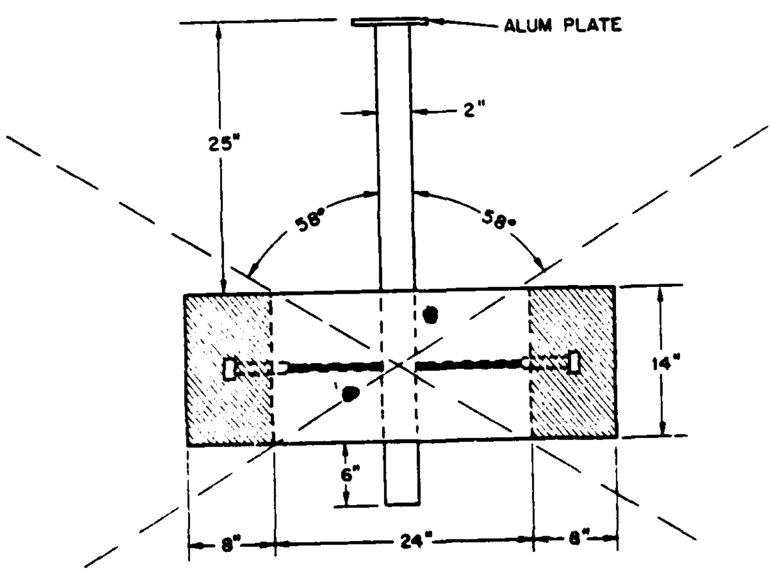


(a) Plan view



(b) Section view

Fig. 1 — Design of buoy

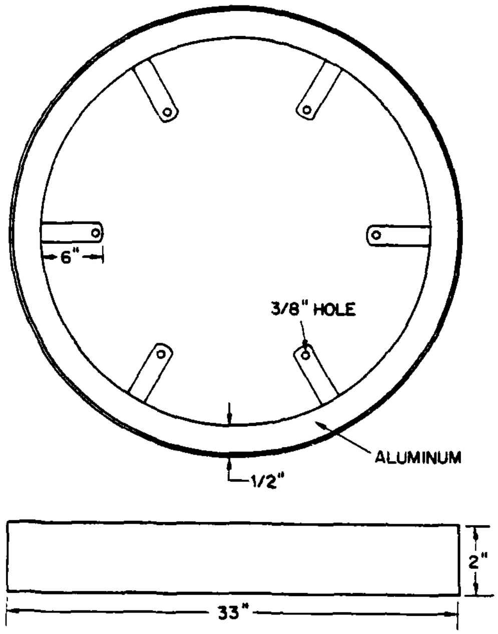


Fig. 2 — Retainer ring

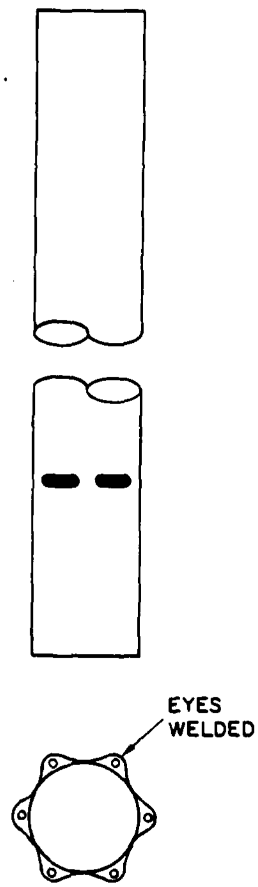


Fig. 3 — View of mast showing mounting eyes

Fig. 4 — Photograph of light mounted on platform

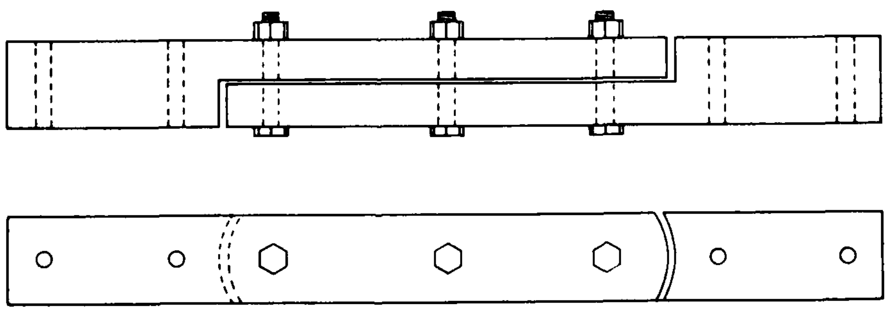


Fig. 5 — Insert used for articulated joint in mast

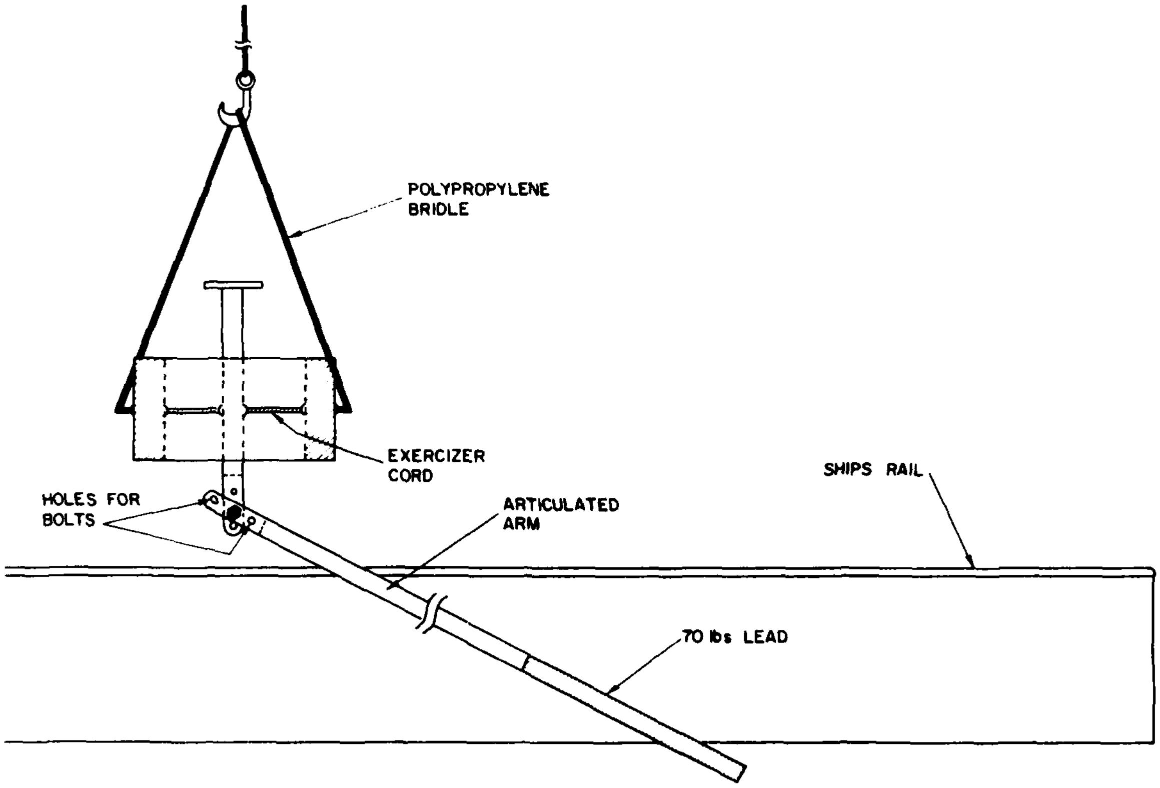


Fig. 6 — Deployment of assembled float and mast

Fig. 7 — Bridle being spliced to eyebolt

Fig. 8 — Photograph of deployed buoy and auxiliary float